Chapter Fifty-Six

HIGHWAY LIGHTING

BUREAU OF DESIGN AND ENVIRONMENT MANUAL

Chapter Fifty-Six
HIGHWAY LIGHTING

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CHAPTER FIFTY-SIX

HIGHWAY LIGHTING

56-1 GENERAL

The primary objective of highway lighting is to enhance highway safety. Lighting enables the driver to determine the geometry and condition of the roadway at extended distances thereby simplifying the driving task. This in turn increases driver comfort and reduces driver fatigue which contributes measurably to highway safety.

Due to the large and diverse volume of highway lighting information, it would be impractical for this chapter to present a complete design guide. The intent of this chapter is to provide the user with a synopsis of the highway lighting design process and to present IDOT's criteria, policies, and procedures on this issue. Use the references listed in Section 56-1.01 as guidance for highway lighting design.

56-1.01 References

For information applicable to IDOT highway lighting design projects, see the following publications:

1. *American National Standard Practice for Roadway Lighting*, ANSI/IESNA RP-8, American National Standards Institute/Illuminating Engineering Society of North America;

2. *An Informational Guide for Roadway Lighting*, American Association of State Highway and Transportation Officials;

3. *National Electrical Code*, National Fire Protection Association;

4. *National Electrical Safety Code*, American National Standards Institute/Institute of Electrical and Electronics Engineers;

5. *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*, American Association of State Highway and Transportation Officials;

6. *Structural Supports for Highway Signs, Luminaires, and Traffic Signals,* National Cooperative Highway Research Program Report No. 411, Transportation Research Board.

7. *A Guide to Standardized Highway Lighting Pole Hardware*, American Association of State Highway and Transportation Officials;

8. *Roadside Design Guide*, American Association of State Highway and Transportation Officials;

9. *Standard Specifications for Road and Bridge Construction*, Illinois Department of Transportation;

10. *Highway Standards*, Illinois Department of Transportation;

11. Electrical Detail Sheets, Illinois Department of Transportation;

12. *Warrants for Highway Lighting*, National Cooperative Highway Research Program Report No. 152, Transportation Research Board;

13. *Partial Lighting of Interchanges*, National Cooperative Highway Research Program Report No. 256, Transportation Research Board;

14. *Illinois Manual on Uniform Traffic Control Devices (ILMUTCD)*, IDOT; and

15. *American National Standard Practice for Tunnel Lighting*, ANSI/IESNA RP-22, American National Standards Institute/Illuminating Engineering Society of North America.

56-1.02 Responsibilities

Each district is responsible for the highway lighting projects within their respective jurisdictions (e.g., information gathering and plan preparation). See Chapter 63 for additional information on plan preparation. The district is also responsible for coordination of Central Office or consultant designs and plan submittals. The district will submit all consultant designs of lighting plans to the Central Office for review and approval by the Electrical and Mechanical Unit. Lighting plans for rest areas and weigh stations will also be reviewed by the Electrical and Mechanical Unit.

District 1 is responsible for highway lighting projects within their jurisdiction. This includes both plan review and approval.

56-1.03 Definitions

The following defines the more commonly used terms in highway lighting design:

1. Average Initial Illuminance. The average level of horizontal illuminance on the pavement area of a traveled way at the time the lighting system is installed when lamps are new

and luminaires are clean; expressed in average footcandles (lux) for the pavement area. See definition of illuminance.

2. Average Maintained Illuminance (E_h). The average level of horizontal illuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factor (MF); expressed in average footcandles (lux) for the pavement area. See definition for maintenance factor.

3. Ballast. An electrical device used with high intensity discharge lamps to provide proper electrical operating characteristics. It limits the electric current through the lamp and may also transform voltage.

4. Candela (cd). A measure of the luminous intensity of a light source as seen by the eye (a.k.a., "candle"). For example, because the eye is less sensitive to blue light than to green light, a blue light source must radiate more power in watts (W) than must a green light source if the two are to have the same luminous intensity. Most light sources have different luminous intensities when viewed from different directions and so the luminous intensity for a light source may vary with the angle at which it is viewed (1 cd = 1 cp).

5. Candela per Square Meter (cd/m^2). The metric unit of luminance (photometric brightness) which is equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square meter (lm/m^2) or the average luminance of any surface emitting or reflecting light at that rate (1 cd/m^2 = 0.2919 fl).

6. Candlepower (cp). The luminous intensity in a specific direction; expressed in candelas (cd). It is no indication of the total light output (1 cp = 1 cd).

7. Coefficient of Utilization (CU). The ratio of the luminous flux (lm) from a luminaire received on the pavement surface to the rated lumens emitted by the luminaire.

8. Disability Glare. Glare resulting in reduced visual performance and visibility. It often is accompanied by discomfort. See definitions for discomfort glare and glare.

9. Discomfort Glare. Glare producing discomfort. It does not necessarily interfere with visual performance or visibility. See definition for glare.

10. Footcandle (fc). The US Customary unit of measurement for illuminance on a surface one square foot (ft^2) in area on which there is uniformly distributed a light flux of one lumen (lm). (1 fc = 10.76 lx).

11. Footlambert (fl). The US Customary unit of luminance (photometric brightness) which is equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot (lm/ft^2) or the average luminance of any surface emitting or reflecting light at that rate (1 fl = 3.426 cd/m^2).

12. Glare. The optical sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted and which causes annoyance, discomfort, or loss in visual performance and visibility. See definitions for disability glare and discomfort glare.

13. House Side. The horizontal direction which is away from the roadway or behind the nadir of the luminaire. See definitions for street side and nadir.

14. Isolux Diagram. A diagram plotted on any appropriate set of coordinates to show all points on a surface for which the illuminance is the same, as represented by a series of isolux line curves.

15. Illuminance. The density of the luminous flux incident on a surface. It is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

16. Lamp Lumen Depreciation Factor (LLD). A depreciation factor that indicates the decrease in a lamp's initial lumen output over time. For design calculations, the initial lamp lumen value is reduced by LLD to compensate for the anticipated lumen reduction. See definition for maintenance factor.

17. Light Standard (Pole). A pole provided with the necessary internal attachments for wiring and the external attachments for the bracket and luminaire.

18. Longitudinal Roadway Line (LRL). A line along the roadway parallel to the curb or shoulder line. See definition for transverse roadway line.

19. Lumen (lm). The unit of luminous flux. It is equal to the flux through a unit solid angle (steradian), from a uniform point source of one candela (cd), or to the flux on a unit surface all points of which are at unit distance from a uniform point source of one candela.

20. Luminaire. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

21. Luminaire Dirt Depreciation Factor (LDD). A depreciation factor that indicates the expected reduction of a lamp's initial lumen output due to the accumulation of dirt on or within the luminaire over time. See definition for maintenance factor.

22. Luminance. The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

23. Luminous Efficacy (lm/W). The quotient of the luminous flux (lm) emitted by the total lamp power input. It is expressed in terms of lumens per watt (lm/W).

24. Luminous Efficiency (%). The ratio of the total luminous flux emitted by a luminaire to that emitted by the bare lamp.

25. Luminous Intensity. See definition of candela.

26. Lux (lx). The metric unit of illuminance on a surface one square meter (m^2) in area on which there is uniformly distributed a light flux of one lumen (lm), or the illuminance produced on a surface for which all points are at a distance of one meter (m) from a uniform point source of one candela (cd) (1 lx = 1 lm/m^2 = 0.0929 fc).

27. Maintenance Factor (MF). A combination of light loss factors used to denote the reduction of the illumination for a given area after a period of time compared to the initial illumination on the same area (MF = LLD • LDD).

28. Mounting Height. The vertical distance between the roadway surface and the center of the light source in the luminaire.

29. Nadir. The vertical axis which passes through the center of the luminaire light source.

30. Overhang. The horizontal distance between a vertical line through the nadir of a luminaire and the edge of traveled way or edge of the area to be illuminated.

31. Setback. The horizontal distance between the face of a light pole and the edge of traveled way.

32. Spacing. The distance in meters between successive light poles.

33. Street Side. The horizontal direction which is toward the roadway from the nadir of the luminaire. See definition of house side.

34. Transverse Roadway Line (TRL). Any line across the roadway that is perpendicular to the curb or shoulder line. See definition of longitudinal roadway line.

35. Uniformity Ratio (E_h/E_{min}). The ratio of average maintained horizontal illuminance (E_h) to the maintained horizontal illuminance at the point of minimum illumination (E_{min}) on the pavement. A uniformity ratio of 3:1 means that E_h — footcandles (lux) is three times the E_{min} — footcandles (lux) at the point of least illuminance on the pavement.

36. Utilization Curve. A plot of the quantity of light falling on the horizontal surface both in front (street side) and behind (house side) the luminaire. It shows only the percent of bare lamp lumens which fall on the horizontal surface and is plotted as a ratio of width of area to mounting height of luminaire.

56-2 GUIDELINES FOR JUSTIFYING HIGHWAY LIGHTING

Providing lighting for all highway facilities is not practical nor cost effective. It is generally IDOT's practice only to provide highway lighting where justified based on sound engineering judgment and on the criteria, recommendations, and principles presented in the latest approved edition of ANSI/IESNA RP-8 publication *American National Standard Practice for Roadway Lighting* and the AASHTO publication *An Informational Guide to Roadway Lighting.*

The Department will assess the economic feasibility of lighting projects and identify candidate locations. A location that appears to justify lighting does not necessarily obligate the Department to provide funding. Local Agencies may provide lighting within their respective jurisdictions provided they find sufficient benefit in the forms of convenience, safety, policing, community promotion, public relations, etc., to participate in an appreciable percentage of the cost of, or wholly finance, the installation, maintenance, and operation of the lighting facilities (see Chapter 5).

For a highway facility to be considered for lighting, the lighting system must be both economically feasible and justified based on the applicable criteria presented in the following sections. The impacts of local conditions (e.g., frequent fog, ice, snow, roadway geometry, ambient lighting, sight distance, signing) also should be considered when analyzing highway lighting needs.

56-2.01 Analyzing Highway Lighting Needs

The AASHTO publication *An Informational Guide to Roadway Lighting* presents an empirical approach to analyzing highway lighting needs with primary application to freeway-type facilities. The principal considerations are vehicular traffic volume, interchange spacing (i.e., an indicator of the relative frequency of vehicular traffic maneuvers), land development and artificial lighting conditions in the area surrounding the freeway, and the night-to-day crash ratio. The affect of these factors on driver visibility should be considered in the lighting needs analysis.

A supplemental approach to analyzing highway lighting needs, based primarily on an analytical evaluation of driver information, is published in NCHRP Report No. 152 *Warrants for Highway Lighting*. This publication has application to both urban-type facilities (e.g., streets, arterials, intersections) and freeway-type facilities (e.g., Interstates). In urban areas where the analyst may find difficulty in applying the AASHTO empirical approach, Report No. 152 offers an alternative approach for analyzing highway lighting needs. Additional information for analyzing partial interchange lighting is available in NCHRP Report No. 256.

56-2.02 Freeways

Use the criteria presented in the following sections when analyzing the lighting needs for State-maintained freeway facilities.

56-2.02(a) Continuous Freeway Lighting

Continuous freeway lighting (CFL) should be considered under the following conditions:

1. Freeway Volume. On those freeway sections in and near cities where the current ADT is 30,000 or more, CFL should be considered.

2. Interchange Spacing. CFL should be considered where three or more successive interchanges are located with an average spacing of 1.5 miles (2.5 km) or less, and adjacent areas outside the right-of-way are substantially urban in character.

3. Land Development/Lighting Conditions. Consider providing CFL where, for a length of 2 miles (3 km) or more, the freeway passes through a substantially developed suburban or urban area in which one or more of the following conditions exist:

   - local traffic operates on a complete street grid having some form of street lighting, parts of which are visible from the freeway;

   - the freeway passes through a series of developments (e.g., residential, commercial, industrial areas, civic areas, colleges, parks, terminals) which include facilities (e.g., roads, streets, parking areas, yards) that are lighted;

   - separate cross streets, both with and without connecting ramps, occur with an average spacing of 0.5 miles (1 km) or less, some of which are lighted as part of the local street system; or

   - freeway cross-section elements (e.g., median, shoulders), are substantially reduced in width below desirable criteria in relatively open country.

4. Night-To-Day Crash Ratio. CFL should be considered where the night-to-day ratio of crash rates is at least 2.0 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. The number of nighttime crashes also should be evaluated.

5. Local Agency Needs. CFL should be provided where the Local Agency finds sufficient benefit in the forms of convenience, safety, policing, community promotion, public relations, etc., to pay an appreciable percentage of the cost of, or wholly finance, the installation, maintenance and operation of the lighting facilities.

56-2.02(b) Complete Interchange Lighting

Complete interchange lighting (CIL) consists primarily of lighting the freeway's through traffic lanes within the interchange area, the traffic lanes of all ramps, the acceleration and deceleration lanes, all ramp terminals, and the crossroad between the outermost ramp terminals. Consider providing CIL at interchanges under the following conditions:

1. Ramp Volume. CIL should be considered where the total current ADT ramp traffic entering and exiting the freeway within the interchange area exceeds 10,000 for urban conditions, 8000 for suburban conditions, or 5000 for rural conditions.

2. Crossroad Volume. Consider providing CIL where the current ADT on the crossroad exceeds 10,000 for urban conditions, 8000 for suburban conditions, or 5000 for rural conditions.

3. Land Development/Lighting Conditions. Consider providing CIL at locations on unlighted freeways where existing substantial commercial or industrial development, which is lighted during hours of darkness, is located in the immediate vicinity of the interchange, or where the crossroad approach legs are lighted for 0.5 miles (1 km) or more on each side of the interchange.

4. Night-To-Day Crash Ratio. CIL should be considered where the night-to-day ratio of crash rates within the interchange area is at least 1.5 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. The number of nighttime crashes also should be evaluated.

5. Local Agency Needs. CIL should be provided where the Local Agency finds sufficient benefit in the forms of convenience, safety, policing, community promotion, public relations, etc., to pay an appreciable percentage of the cost of, or wholly finance, the installation, maintenance and operation of the lighting facilities.

6. Continuous Freeway Lighting. Provide CIL at interchanges where continuous freeway lighting is provided. See Section 56-2.02(a).

56-2.02(c) Partial Interchange Lighting

Partial interchange lighting (PIL) generally is a lighting configuration that consists of a few luminaires located in the vicinity of some or all ramp terminals. The usual practice is to light those general areas where the exit and entrance ramps connect with the through traffic lanes of the freeway and generally those areas where the ramps intersect the crossroad. Consider providing PIL at interchanges under the following conditions:

1. Ramp Volume. Consider providing PIL where the total current ADT ramp traffic entering and exiting the freeway within the interchange area exceeds 5000 for urban conditions, 3000 for suburban conditions, or 1000 for rural conditions.

2. Freeway Volume. Consider providing PIL where the current ADT on the freeway through traffic lanes exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions.

3. Night-To-Day Crash Ratio. PIL should be considered where the night-to-day ratio of crash rates within the interchange area is at least 1.25 or higher than the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. The number of nighttime crashes also should be evaluated.

4. Local Agency Needs. PIL should be provided where the Local Agency finds sufficient benefit in the forms of convenience, safety, policing, community promotion, public relations, etc., to pay an appreciable percentage of the cost of, or wholly finance, the installation, maintenance and operation of the lighting facilities.

5. Continuous Freeway Lighting. Consider providing PIL where continuous freeway lighting is justified, but not initially installed. See Section 56-2.02(a). The freeway section should be in or near a city where the current ADT is 30,000 or more, or the interchange should be among three or more successive interchanges located with an average spacing of 1.5 miles (2.5 km) or less with adjacent areas outside the right-of-way being substantially urban in character.

6. Complete Interchange Lighting. Where complete interchange lighting is justified, but not initially fully installed, a partial lighting system which exceeds the normal partial installation in number of lighting units is considered to be justified. See Section 56-2.02(b).

NCHRP Report No. 256 *Partial Lighting of Interchanges* provides additional information on analyzing the need for partial interchange lighting.

56-2.02(d) Crossroad Ramp Terminal Lighting

Where the crossroad ramp terminal design of freeway interchanges incorporates raised channelizing or divisional islands or where there is poor sight distance, lighting of the crossroad ramp terminal should be considered regardless of traffic volume.

56-2.03 Streets and Highways Other Than Freeways

Urban and rural conditions, traffic volumes (both vehicular and pedestrian), intersections, turning movements, signalization, channelization, and varying geometrics are factors that should be considered when determining the lighting needs of streets and highways other than freeways. Consider the following when assessing the lighting needs of such State-maintained facilities:

1. Facilities with Raised Medians. Consider highway lighting along sections of State-maintained facilities that have raised medians.

2. Major Urban Arterials. Consider highway lighting along all major arterials that are located in urban areas.

3. Intersections. Consider intersection lighting at rural intersections that meet any one of the following conditions:

   - there are 2.4 or more crashes per million vehicles in each of three consecutive years;

   - there are 2.0 or more crashes per million vehicles per year and 4.0 or more crashes per year in each of three consecutive years;

   - there are 3.0 or more crashes per million vehicles per year and 7.0 or more crashes per year in each of two consecutive years;

   - the intersection is signalized and there have been, in the past year, 5.0 or more reported nighttime crashes and a day-to-night crash ratio of less than 2.0;

   - substantial nighttime pedestrian volume exists;

   - less than desirable alignment exists on any of the intersection approaches;

   - the intersection is an unusual type requiring complex turning maneuvers;

   - commercial development exists in the vicinity which causes high nighttime traffic peaks;

   - distracting illumination exists from adjacent land development; and/or

   - there exists recurrent fog or industrial smog in the area.

   Isolated intersections located within the fringe of corporate limits which are suburban or rural in character may be illuminated at State expense provided they meet the above criteria. Every effort should be made to have the Local Agency accept ownership of the system after installation and assume all operational and maintenance costs (see Chapter 5).

4. High Conflict Locations. Consider providing lighting along roadway sections with high vehicle-to-vehicle interactions (e.g., sections with numerous driveways, significant commercial or residential development, high percentage of trucks). Lighting generally improves traffic safety and efficiency at such locations.

5. Complex Roadway Geometry. Consider providing lighting at spot locations in rural areas where the driver is required to pass through a roadway section with complex geometry.

6. Night-To-Day Crash Ratio. Lighting should be considered at locations or sections of streets and highways where the night-to-day ratio of crash rates is higher than the statewide average for similar locations, and a study indicates that lighting may be expected to significantly reduce the night crash rate. The number of nighttime crashes also should be evaluated.

7. Local Agency Needs. Lighting should be provided where the Local Agency finds sufficient benefit in the forms of convenience, safety, policing, community promotion, public relations, etc., to pay an appreciable percentage of the cost of, or wholly finance, the installation, maintenance and operation of the lighting facilities. For additional information on lighting responsibilities of Local Agencies, see Chapter 5.

56-2.04 Rest Areas

The Electrical and Mechanical Unit is responsible for the design of rest area facility lighting. Provide lighting at rest areas that offer complete rest facilities (e.g., comfort station, information kiosk, picnic areas). Illuminate all areas within the facility that have pedestrian activities (e.g., parking areas, immediate area of building). Provide lighting at rest area ramps, gore areas, and other decision points.

56-2.05 Weigh Stations

The Electrical and Mechanical Unit is responsible for the design of weigh station facility lighting. Provide lighting at all permanent truck weigh stations where weighing occurs after daylight hours. Illuminate the weighing area, parking area, speed change lanes, ramps, and gore areas. Overheight detectors also are the responsibility of the Electrical and Mechanical Unit.

56-2.06 Bridge Structures and Underpasses

Because of their typical configuration and length-to-height ratio, underpasses generally have good daylight penetration and do not require supplemental daytime lighting. Underpass lighting generally is installed to enhance driver visibility after daylight hours. When the length-to-height ratio of the underpass exceeds approximately 10:1, it usually is necessary to analyze specific geometry and roadway conditions, including vehicular and pedestrian activity, to determine the need for supplemental daytime lighting.

On highways that are not continuously lighted, consider providing underpass lighting where frequent nighttime pedestrian traffic exists through the underpass or where unusual or critical geometry exists within or on an approach to the underpass.

Provide underpass lighting on all highways that are continuously lighted. Favorable positioning of conventional highway luminaires adjacent to a relatively short underpass often can provide adequate illumination within the underpass without a need to provide supplemental lighting. If this action is considered, ensure that shadows cast by the conventional luminaires do not become a visibility problem within the underpass.

56-2.07 Tunnels

A tunnel is defined as a structure of any type surrounding a vehicular roadway which requires the use of artificial lighting or equivalent means to provide adequate roadway visibility necessary for safe and efficient traffic operation. Daytime tunnel lighting is justified when driver visibility requirements are not satisfied without the use of a lighting system to supplement natural sunlight. Visibility requirements vary considerably with such items as:

- portal to portal tunnel length (i.e., short or long);
- tunnel portal design;
- geometry of tunnel and its approaches;
- vehicular and pedestrian traffic characteristics;
- treatment of pavement, portal, interior, and environmental reflective surfaces;
- climate and orientation of tunnel; and
- visibility objectives to provide for safe and efficient tunnel operation.

Use the requirements in the *American National Standard Practice for Tunnel Lighting* for tunnel lighting designs.

56-2.08 Other Locations

Provide lighting for all pedestrian underpass and pedestrian tunnel facilities. In addition, the need to provide lighting for the following facilities will be determined on a case-by-case basis:

- commuter park-and-ride lots,
- bike paths,
- pedestrian walkways, and
- pedestrian overpasses.

56-2.09 Highway Sign Illumination

Most highway signs are manufactured with reflective sheeting so that, when illuminated by vehicular headlights, the sign message is reflected back to the driver. Signs also may be internally or externally illuminated by a direct light source. Note that conventional highway luminaires generally do not meet the requirements for external sign illumination where justified.

In general, provide sign illumination where background lighting obscures the legend of the sign, the sign is not adequately visible, or there is nearby highway lighting. In urban areas, the external illumination of overhead panel signs generally is warranted. Provide external lighting for all overhead panel signs along lighted highway facilities. Truss-mounted signs should be externally illuminated. Cantilever-mounted panel signs on non-lighted facilities will be illuminated on a case-by-case basis. Consider providing external lighting for overhead panel signs at interchanges or intersections where there exists a high volume of traffic. If complete interchange lighting exists, provide external lighting for all overhead panel signs at the interchange. See the *Illinois Manual on Uniform Traffic Control Devices* for additional information.

56-2.10 Navigation and Obstruction Lighting

Highway structures over navigable waterways require waterway obstruction warning luminaires in accordance with U.S. Coast Guard requirements. The district or Central Office will coordinate with the Coast Guard. Any need for aviation obstruction warning luminaires on highway structures will be coordinated with the Federal Aviation Administration by the Central Office. For information on navigable airspace obstructions, consult the FAA Advisory Circular AC 70/7460-2J *Proposed Construction or Alteration of Objects that May Affect the Navigable Airspace*.

56-2.11 Transition Lighting

The need to provide step-down transition lighting, or similar vision-adjustment measures, for traffic lanes emerging from a lighted area will be determined on a case-by-case basis. Contact the Electrical and Mechanical Unit for additional information.

56-2.12 Roadway Reconstruction

During roadway reconstruction projects, existing highway lighting should be evaluated and upgraded or removed, if necessary, to meet current Department highway lighting criteria.

56-2.13 Temporary and Replacement Lighting

The need to provide temporary highway lighting will be considered on a case-by-case basis. For example, construction zones requiring complex traffic maneuvers (e.g., crossovers) may justify the provision of temporary lighting. In addition, if existing lighting is affected or relocated during construction, temporary replacement lighting should be provided in like kind and quality during the construction phase.

56-2.14 Municipal and Residential Lighting

IDOT will not participate in highway lighting on facilities located within an incorporated area except as described in Sections 56-2.02 and 56-2.03 and Chapter 5.

56-2.15 Ornamental Lighting

There are some ornamental lighting luminaires with distribution patterns that will control the light and meet ANSI/IESNA RP-8 requirements. At the request of a Local Agency, ornamental lighting may be permitted by the Department on a State-maintained facility if the Department's minimum requirements are met and the Local Agency is wholly responsible for construction funding, ownership, electrical energy, and maintenance of such lighting both during and after construction. Contact the Electrical and Mechanical Unit for additional information on permitting ornamental lighting.

56-3 MATERIALS AND EQUIPMENT

Because luminaires, electrical devices, and support structures change rapidly with new developments, this section presents an overview rather than an absolute requirement for lighting equipment and materials. See the *Standard Specifications, Highway Standards,* and the IDOT electric detail sheets for details on lighting equipment and materials that may be used on projects. Section 56-5 provides specific design guidance for luminaires, electrical devices, and support structures used by IDOT. Figure 56-3A illustrates the various components of a typical highway lighting structure.

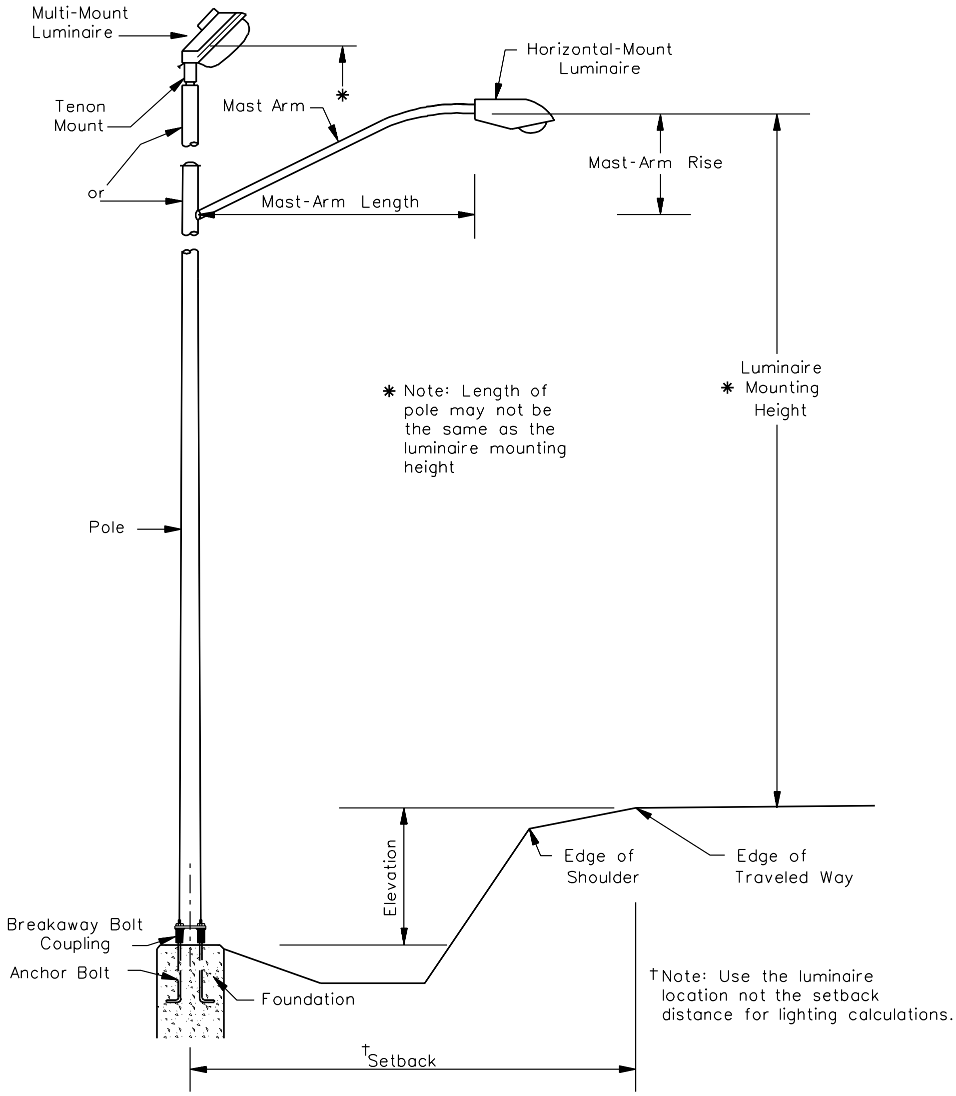
56-3.01 Foundations and Mounting

In conventional highway lighting applications, luminaire assemblies generally are attached to poles mounted along the roadway either on ground foundations or atop bridge parapets. Supports for conventional light poles may be either reinforced concrete or steel helix foundations and are constructed from typical designs. However, concrete foundations for light towers in high-mast lighting applications require special designs and soil analyses to determine adequate depth and support. Depending on factors such as roadside location, most conventional light poles will be mounted on breakaway devices. Light poles that are mounted atop parapets and barriers are attached using high-strength, non-breakaway bolts. Special vibration isolating materials are used to mount light poles on bridges. At signalized intersections, a roadway luminaire also may be mounted on a combination mast-arm assembly and pole.

Luminaires mounted in underpasses and tunnels are either attached directly to the wall adjacent to or hung from vibration-dampening pendants above the travel lanes. Light sources that are used to externally illuminate overhead sign panels typically are fastened to the truss or cantilever support structure. Waterway and aviation obstruction warning luminaires are attached directly to the structures representing the hazard.

56-3.02 Pole Bases

Light poles may be mounted on one of several types of bases (e.g., stainless steel flair base, transformer base, breakaway coupling base, anchor base, butt base). Selection is governed by project need. A very important distinguishing characteristic of the pole base is whether or not it is classified by AASHTO and FHWA as an acceptable breakaway device. If the pole represents a roadside hazard, it will be mounted on a breakaway device (see Chapter 38 for additional guidance). Section 56-5.05 provides design guidance on this issue. The following briefly describes the pole bases used by the Department:



Note: *Single mast arm/multi-mount luminaire shown for illustrative purposes. For other luminaire mounting types, see the IDOT electric detail sheets,* Highway Standards*, and the* Standard Specifications*.*

TYPICAL HIGHWAY LIGHTING STRUCTURE
Figure 56-3A

1. Breakaway Bolt Coupling. Breakaway bolt couplings are connectors or sleeves that are designed to shear when the pole is hit by an errant vehicle. The bottom of each coupling is threaded onto a foundation anchor bolt, and the pole is attached to the top of the coupling. Four couplings are used with each pole. All wiring at the pole base will have quick disconnect splices.

2. Frangible Transformer Base. The frangible transformer base consists of a cast aluminum apron between the foundation and the base of the pole. It is designed to deform and break away when hit by an errant vehicle. All wiring inside the base will have quick disconnect splices.

3. Anchor Base. The anchor base consists primarily of a metal plate that is welded to the bottom of the pole. The plate allows the pole to be bolted directly to the foundation using high-strength anchor bolts without an intermediate breakaway connection. The anchor base is not a breakaway device.

56-3.03 Poles

Light poles for conventional highway lighting applications support luminaire mounting heights ranging from approximately 30 ft to 65 ft (9 m to 19.8 m). They may be fabricated as tapered or straight, single-section poles from materials such as aluminum, galvanized steel, stainless steel, weathering steel, fiberglass, and wood. Light towers for high-mast lighting applications generally range from 80 ft to 160 ft (24 m to 49 m) and are designed in multiple sections. Weathering steel is a common material choice for light towers.

56-3.04 Arm Extensions

Depending on the particular application, luminaires may be mounted on mast arms, davit arms, tenon and bracket arms, etc., in a single- or dual-luminaire configuration at the top of the pole. Using arm extensions will place the light source closer to the traveled way while allowing the pole to be located further from the edge of the traveled way.

56-3.05 Luminaires

A luminaire is a complete lighting unit consisting of a lamp, or lamps, together with the parts necessary to regulate and distribute the light. The following sections provide some general information on the basic components of the luminaire.

56-3.05(a) Light Sources

There are numerous light sources for highway lighting applications. However, there are only a few practical choices when considering availability, size, power requirements, and cost effectiveness. It is rare that a light source other than the high-intensity discharge type is used in highway lighting applications. However, fluorescent lamps have been used to illuminate signs. The following provides information on some of the high-intensity light sources used in highway applications:

1. High Pressure Sodium (HPS). HPS lamps have excellent luminous efficiency, power usage, and long life. The HPS lamp produces a soft, pinkish-yellow light by passing an electric current through a combination of sodium and mercury vapors.

2. Low Pressure Sodium (LPS). LPS lamps are considered one of the most efficient light sources on the market. However, the LPS lamp is very long and produces a very pronounced yellow light. Light is produced by passing an electrical current through a sodium vapor.

3. Mercury Vapor (MV). Prior to the introduction of HPS lamps, MV was the most commonly used light source in highway applications. The MV lamp produces a bluish-white light and is not as efficient as the HPS lamp.

4. Metal Halide (MH). MH lamps produce better color at higher efficiency than MV lamps. However, life expectancy for MH lamps is shorter than for HPS or MV lamps. They also are more sensitive to lamp orientation (i.e., horizontal vs. vertical) than other light sources. MH lamps produce good color rendition. Light is produced by passing a current through a combination of metallic vapors.

56-3.05(b) Optical System

The optical system of the luminaire consists of a light source, a reflector, and usually a refractor. The following provides a general discussion on the optical system components:

1. Light Source. See section 56-3.05(a) for information on the high-intensity discharge lamps used in highway applications.

2. Reflector. The reflector is used to redirect the light rays emitted by the lamp. Its primary purpose is to redirect that portion of light emitted by the lamp that would otherwise be lost or poorly utilized. Reflectors are designed to function alone or, more commonly, with a refractor to redirect the poorly utilized portion of light to a more desirable distribution pattern. Reflectors are classified as either specular or diffused. Specular reflectors are made from a glossy material that provides a mirror-like surface. Diffuse reflectors are used where there is a need to spread light over a wider area.

3. Refractor. The refractor is another means of optical control to change the direction of the light. Refractors are made of a transparent, clear material, usually high-strength glass or plastic. The refractor, through its prismatic construction, controls and redirects both the light emitted by the lamp and the light redirected by the reflector. It also can be used to control the brightness of the lamp source.

56-3.05(c) Ballasts

All luminaires used in highway lighting applications have a built-in ballast. Ballasts are used to regulate the voltage to the lamp and to ensure that the lamp is operating within its design parameters. It also provides the proper open circuit voltage for starting the lamp.

56-3.05(d) Housing Units

The housing integrates the lamp, reflector, refractor, and ballast into a self-contained unit. The housing is sealed to prevent dust, moisture, and insects from entering. Air entering the housing for thermal breathing will typically pass through a filter to eliminate contaminates. Housing units are designed to accommodate access for lamp maintenance and adjustment (i.e., light direction and distribution).

56-3.06 Other Materials and Equipment

There are numerous other materials and equipment that are used in a highway lighting system such as quick disconnect fuseholders, controllers, photocells, surge arresters, raceways, ground rods, cabling, transformers, conduit, handholes, and pullboxes. The use and specification of such ancillary items will depend on the particular highway lighting application and will vary on a project-by-project basis.

56-4 LIGHTING PROJECTS (New)

The following is a brief overview of the development of a highway lighting design project.

56-4.01 Determine Classifications and Justify Need

Determine the roadway classification, area classification, pavement classification, and environmental conditions. A mutual determination will be made between the district and the Central Office regarding the classification of any interchange or freeways as urban, suburban, or rural. The district will initiate a lighting project by submitting the warrants and all supporting data to the Central Office for review. Highway lighting projects that are justified will be incorporated into the annual improvements program.

56-4.02 Assemble Information

Assemble all necessary information. This may include:

- contacting the district and/or Electrical and Mechanical Unit for current design policies and procedures and for copies of any available sample calculations, plans, notes, schedules, and pay quantities;
- gathering, from the district office, the necessary roadway and bridge plan and profile sheets and any special detail sheets (e.g., overhead signs);
- determining existing and proposed utility locations;
- discussing special considerations with the highway or bridge designer;
- conducting field reviews; and
- contacting local officials for local projects.

56-4.03 Prepare Preliminary Plans

Prepare all components necessary for preliminary plan submittal. The district will submit to the Central Office plan sheets showing the overall project but need not include non-lighting details. Ensure that the plans include:

- stationing at appropriate intervals and stationing of noses and tangent points of ramps which are formed by the roadway proper and not by the shoulder;
- pavement, shoulder, and median widths at frequent intervals;

- all roadway features which may affect the stationing or setback of poles (e.g., guardrail, barrier median, barrier curb, signs exceeding 50 ft^2 (4.5 m^2), driveways, culverts, railroads, pipelines);
- the approximate height of any power and telephone lines over the roadway;
- the location of power poles from which service may be obtained; and
- if signals are present or proposed, the location of the power pole and control cabinet.

56-4.04 Central Office Review

Upon receipt of the preliminary plans, the Electrical and Mechanical Unit in the Central Office will determine the location of poles and luminaires, design the electrical distribution and control system, and prepare specifications. The Electrical and Mechanical Unit also will furnish wiring diagrams and drawings of equipment, foundations, and electrical details. The plans and specifications will be returned to the district for completion.

When a consultant is used by the district to complete the design, the preliminary and final plans will be submitted to the Electrical and Mechanical Unit for review and approval.

56-4.05 Field Review

Prior to finalizing plans, the district or consultant will conduct a field review to determine if pole and luminaire locations will interfere with existing or proposed underground, at-grade, and aerial roadway structures. The district will notify the Electrical and Mechanical Unit of any conflict that would cause modification to the design. For high-mast lighting designs, ensure that borings are taken for soil analyses to ascertain the correct foundation depth at each tower location.

56-4.06 Final Plan Preparation/Contract Award

The district will prepare the final plans, specifications, and estimates and submit them to the BDE for processing and contract award. See Chapter 63 for information on plan preparation and Chapter 66 for information on contract processing. Upon award of the contract, the contractor will submit for approval a list of manufacturers for all major electrical equipment to be used on the project (e.g., poles, towers, luminaires, controllers, unit duct, cable), a complete set of manufacturer’s product data, and detailed shop drawings for any fabricated equipment.

56-4.07 Final Inspection

The completed project will be inspected by the Electrical and Mechanical Unit from the Central Office in accordance with the *Standard Specifications*. If the installation is satisfactory, it will be accepted.

56-5 LIGHTING DESIGN

When designing a highway lighting system, there are numerous factors to consider. This section presents design considerations commonly encountered in highway lighting designs and presents IDOT's criteria, policies, and procedures on these issues. Figure 56-5A presents typical highway lighting design parameters used by the Department.

TYPICAL IDOT HIGHWAY LIGHTING DESIGN PARAMETERS	
Maintenance Factor (i.e., LLD • LDD)	0.54 to 0.81
Percent of Voltage Drop Allowed	5%
Typical Parameters for Conventional Lighting (Interstate — Rural)	Aluminum or Steel Pole Single- or Twin-Tenon Mounting 45 ft to 55 ft (13.7 m to 16.8 m) Mounting Height 250 W or 400 W HPS Multi-Mount Luminaire Breakaway Base where Justified
Typical Parameters for Conventional Lighting (Interstate — Urban)	Aluminum Pole Davit or Mast-Arm Mounting 35 ft to 45 ft (10.7 m to 13.7 m) Mounting Height 250 W or 400 W HPS Horizontal-Mount Luminaire IES Classification: Cut-Off or Semi-Cutoff
Typical Pavement Classification	Class R3
Typical IES Luminaire Classification For Conventional Highway Lighting	Type II, Type III, or Type IV Medium Distribution (M) Cut-Off (C) or Semi-Cutoff (S)
Typical Luminaire Pole Arrangement	Staggered, Opposite, or Same Side

TYPICAL IDOT HIGHWAY LIGHTING DESIGN PARAMETERS

Figure 56-5A

56-5.01 Methodologies

There are three lighting design methodologies available for use in highway lighting design — illuminance, luminance, and small-target-visibility. The Illuminating Engineering Society (IES) of North America has been a leader in developing these methodologies (see the publication *American National Standard Practice for Roadway Lighting*, ANSI/IESNA RP-8). The illuminance methodology is used for a majority of IDOT lighting projects. It is a good practice, and will be required in consultant submittals, to consider both illuminance and a luminance design. Select the design that produces the most conservative results. Both of these methodologies require the designer to consider veiling luminance and limit the ratio to the values listed in Figures 56-5B and 56-5C. The following sections briefly describe each of the available design methodologies.

56-5.01(a) Illuminance

The illuminance methodology is the oldest and simplest to use of the three methodologies. Experience has shown this design methodology to be very effective. Illuminance is defined as the density of the luminous flux, lumen (lm), incident on a surface area, ft^2 (m^2), and is measured in footcandles (lux). The illuminance methodology is used to determine the combined amount of luminous flux reaching critical pavement locations from contributing luminaires (i.e., a measure of light quantity) and to assess how uniformly the luminaires' combined luminous flux is horizontally distributed over the pavement surface (i.e., a measure of light quality). The brightest spot normally will occur directly under the luminaire and diminishes as the driver travels away from the source. An inherent disadvantage of the illuminance methodology is that it only accounts for incident light and does not assess the affect on visibility due to reflected light from an object or surface. This sensation is known as "brightness." Objects are distinguished by contrast from their difference in brightness. Brightness is expressed mathematically as luminance — the luminous intensity per unit area directed towards the eye. See Section 56-5.01(b).

The design factors used in illuminance designs are the average maintained horizontal illumination (E_h), or quantity of light, and the uniformity ratio, or quality of light. See Section 56-1.03 for the definition of uniformity ratio (E_h/E_{min}).

56-5.01(b) Luminance

Luminance is defined as the luminous intensity, candela (cd), of any surface in a given direction per unit of projected area, ft^2 (m^2), of the surface as viewed from that direction. It is measured in footcandles (candelas per square meter). The luminance methodology is used to simulate driver visibility by assessing the quantity and quality of light reflected by the pavement surface to the motorist's eye from contributing luminaires. Assumptions are made regarding the spatial positioning of the driver's eye, and luminance values are calculated at grid points over the pavement surface. In theory, luminance is a good measure of visibility; however, the results of using the luminance methodology in highway lighting applications are greatly affected by one's ability to accurately estimate the reflectance characteristics of the pavement surface, both now and in the future. Factors affecting pavement reflectivity include initial surface type, pavement deterioration, resurfacing material type, assumptions regarding weather conditions, etc. It is difficult to predict or control such factors. Compared to illuminance, the luminance methodology is considerably more complicated to understand and use.

The design factors in luminance design include average maintained luminance (L_{avg}), minimum luminance (L_{min}), maximum luminance (L_{max}), maximum veiling luminance (L_v), and ratios of L_{avg} to L_{min}, L_{max} to L_{min}, and L_v to L_{avg}.

56-5.01(c) Small-Target-Visibility (STV)

IES has proposed STV as an alternative lighting design methodology to better define actual driver visibility requirements. Both luminance and STV are considerably more complex than illuminance. Luminance designs depend on pavement reflectance characteristics, observer position, and luminaire location and performance. STV designs depend on identical parameters and add the complexity of an array of 7 in (180 mm), flat targets placed perpendicularly to the pavement surface. The STV methodology is used to calculate the collective visibility of the targets, expressed as a weighted average, for a given design. Theoretically, STV should closely approximate actual driver visibility; however, there is not yet sufficient field experience to calibrate the STV model. See ANSI/IESNA RP-8, Annex A for STV calculations.

56-5.02 Computerized Design

The highway lighting design process is an iterative process that is quite effectively implemented by computer. If criteria are not initially satisfied, it will be necessary to change design parameters (e.g., pole spacing, mounting height, luminaire wattage) until an acceptable alternative is found. This process will be repeated until the design is optimized to meet the selected criteria.

For computerized designs prepared by outside consultants, the consultant will provide the program's name and version and the input data and output reports in both printed and electronic format. The consultant is encouraged to use available software packages for highway lighting design. Several manufacturers of highway lighting equipment offer such programs. In addition, the Illuminating Engineering Society of North America publishes annually a compilation of software packages available for highway lighting design purposes. When used, ensure that the software program selected meets or exceeds ANSI/IESNA RP-8 requirements. Contact the Electrical and Mechanical Unit in the Central Office for a list of approved software programs.

56-5.03 Design Process

The following briefly describes the processes used in any highway lighting design:

1. Select Lighting Equipment. Select the lighting equipment and associated design parameters that will be used for the project. This will include items such as luminaire mounting height, pole setback, light source, lamp wattage, etc. It will be necessary to make some initial assumptions during preliminary design. Design parameters then may be iteratively changed to meet the highway lighting criteria.

2. Select Luminaire Arrangement. Select an appropriate luminaire arrangement for the project. This will depend on local site conditions and engineering judgment. Alternative arrangements may need to be considered.

3. Luminaire Spacing. Typically, luminaire spacing will be determined by computer software. For manual calculations, Equation 56-5.1 should be used. Footcandle (fc) and lux (lx) are units of illuminance expressed in lumens (lm) per square foot (ft^2) and lumens per square meter (m^2), respectively. Therefore, the average horizontal footcandle (lux) on a highway is equal to the total lumens cast on the highway by a single unit divided by the spacing between units times the width of the roadway. Total lumens that a luminaire will cast on the roadway equals lamp lumens at replacement time times the coefficient of utilization times the luminaire maintenance factor. This relationship can be rearranged to solve for luminaire spacing(s) as shown in Equation 56-5.1.

$$S = \frac{LL \bullet CU \bullet MF}{E_h \bullet W} \qquad \text{Equation 56-5.1}$$

Where:
- S = luminaire spacing — ft (m)
- LL = initial lamp lumens — lm
- CU = coefficient of utilization
- MF = maintenance factor (i.e., LLD • LDD)
- E_h = average maintained horizontal illumination — fc (lx)
- W = width of lighted roadway — ft (m)

4. Check Uniformity. Once luminaire spacing has been determined, check the uniformity of light distribution and compare this value to the lighting criteria selected in Step #1. Adjust design parameters and recalculate as necessary to meet criteria. Use Equation 56-5.2 to determine the uniformity ratio.

$$UR = \frac{E_h}{E_{min}} \qquad \text{Equation 56-5.2}$$

Where:
- UR = uniformity ratio
- E_h = average maintained horizontal illuminance
- E_{min} = maintained horizontal illuminance at the point of minimum illumination on the pavement

5. Select Optimum Design. Because computerized design is relatively quick and easy, consider developing and testing several alternative designs. It generally is not good engineering practice to consider only one design, even if found to satisfy the lighting criteria. There often are several alternatives that will work. Optimize and select the most cost-effective and maintenance-free design.

56-5.04 Design Considerations

When selecting design criteria for a lighting project, it is necessary to determine classifications for the roadway facility, the area the roadway traverses, and the pavement type. The following sections discuss these classifications for the purpose of highway lighting design only.

56-5.04(a) Roadway Classification

Use the following definitions to classify roadway facilities for IDOT highway lighting projects:

1. Freeway. A divided major highway with full control of access and with no crossings at grade.

2. Expressway. A divided major arterial highway for through traffic with full or partial control of access and generally with interchanges at major crossroads. Expressways for non-commercial traffic within parks and park-like areas generally are known as parkways.

3. Major. The part of the roadway system that serves as the principle network for through traffic flow. The routes connect areas of principle traffic generation and important rural highways entering the city.

4. Collector. The distributor and collector roadways serving traffic between major and local roadways. These are roadways used mainly for traffic movements within residential, commercial, and industrial areas.

5. Local. Roadways used primarily for direct access to residential, commercial, industrial, or other abutting property. They do not include roadways carrying through traffic. Long local roadways generally will be divided into short sections by the collector roadway system.

6. Alley. A narrow public way within a block, generally used for vehicular access to the rear of abutting properties.

7. Sidewalk. Paved or otherwise improved areas for pedestrian use, located within public street right-of-way which also contains roadways for vehicular traffic.

8. Pedestrian Way. Public sidewalks for pedestrian traffic generally not within rights-of-way for vehicular traffic roadways. Included are skywalks (pedestrian overpasses), subwalks (pedestrian tunnels), walkways giving access to park or block interiors, and crossings near centers of long blocks.

9. Bicycle Lane. Any facility that explicitly provides for bicycle travel.

56-5.04(b) Area Classification

For IDOT lighting projects, use the following definitions to classify the area in which the roadway traverses:

1. Commercial. That portion of a municipality in a business development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak traffic or a sustained high pedestrian volume and a continuously heavy demand for off-street parking space during business hours. This definition applies to densely developed business areas outside of, as well as those that are within, the central part of a municipality.

2. Intermediate. That portion of a municipality which is outside of a downtown area but generally within the zone of influence of a business or industrial development, often characterized by a moderately heavy nighttime pedestrian volume and a somewhat lower parking turnover than is found in a commercial area. This definition includes densely developed apartment areas, hospitals, public libraries, and neighborhood recreational centers.

3. Residential. A residential development, or mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover at night. This definition includes areas with single family homes, townhouses, and/or small apartments. Regional parks, cemeteries, and vacant lands also are included.

56-5.04(c) Pavement Classification

For IDOT lighting projects, use the following definitions to classify the pavement type of the roadway facility:

1. Class R1. Class R1 pavement has a mostly diffuse mode of reflectance. R1 pavements include Portland cement concrete road surfaces and asphalt road surfaces with a minimum of 15% of the aggregates composed of artificial brightener (e.g., Synopal) aggregates (e.g., labradorite, quartzite).

2. Class R2. Class R2 pavement has a mixed diffuse and specular mode of reflectance. R2 pavements include asphalt road surfaces with an aggregate composed of a minimum 60% gravel with a size greater than 3/8 in (10 mm).

3. Class R3. Class R3 has a slightly specular mode of reflectance. R3 pavements include asphalt road surfaces, both regular and seal coats, with dark aggregates (e.g., trap rock, blast furnace slag) and exhibit a rough texture after some months of use. Class R3 pavement represents typical asphalt highways and is used on most highway lighting projects.

4. Class R4. Class R4 pavement has a mostly specular mode of reflectance. R4 includes asphalt road surfaces with a very smooth texture.

56-5.04(d) Illuminance and Luminance Design Levels

Design criteria for highway lighting projects vary according to the roadway classification and luminance. Figures 56-5B and 56-5C present the illuminance design criteria used by the Department. In addition to these figures, consider the following:

1. Crossroads at Interchanges. Lighting levels on crossroad approaches should not be reduced through an interchange area. If existing crossroad lighting currently is deemed inadequate, it should be considered for upgrading to ensure safe and efficient traffic operation.

2. Partial Interchange Lighting. Where partial interchange lighting is provided, luminaires should be located to best light the through lanes and speed change lanes at diverging and merging locations. The design controls of basic level of lighting and uniformity should be subordinated to overall lighting of the roadway area at these locations.

3. Bridge Structures and Underpasses. Where justified, underpass lighting level and uniformity ratios should duplicate, to the extent practical, the lighting levels on the adjacent facility. On continuously lighted freeways and lighted interchanges, the lighting of bridges and overpasses should be at the same level and uniformity as the roadway.

4. Transition Lighting. Transition lighting is a technique intended to provide the driver with a gradual reduction in lighting levels and glare when leaving an illuminated area. The designer should consider transition lighting if a study of the specific conditions at a location indicates a need. Several implementation methods exist. Contact the Electrical and Mechanical Unit in the Central Office for approved methods of implementation. In addition, the designer also may consider extending delineation 1000 ft (300 m) beyond the last luminaire for traffic lanes emerging from a lighted area. This will provide an additional measure of effectiveness. Vision adjustment when approaching a lighted area is not impacted greatly and therefore requires no special consideration.

5. Navigation and Obstruction Lighting. The lumen output for waterway and aviation obstruction luminaires will be based on the requirements of the U.S. Coast Guard and the Federal Aviation Administration, respectively.

6. Other Locations. Where lighting is justified for tunnels, overhead signing, and other facilities not covered under this section, the criteria presented in the publication ANSI/IESNA RP-8 and the AASHTO publication *An Informational Guide for Roadway Lighting* should be used. Contact the Electrical and Mechanical Unit for additional information on lighting criteria.

<table>
<tr><th rowspan="3">Roadway Facility Classification ④</th><th rowspan="3">Area Classification ③ (Pedestrian Conflict Area)</th><th colspan="3">AVERAGE MAINTAINED ① HORIZONTAL ILLUMINANCE (E_h) footcandle (lux)</th><th rowspan="3">UNIFORMITY RATIO (Ave./Min.)</th><th rowspan="3">VEILING LUMINANCE RATIO L_{Vmax}/L_{avg}</th></tr>
<tr><th colspan="3">Pavement Classification ④</th></tr>
<tr><th>R1</th><th>R2 & R3</th><th>R4</th></tr>
<tr><td>Freeway ②</td><td>Class A
Class B</td><td>0.6 (6)
0.4 (4)</td><td>0.9 (9)
0.6 (6)</td><td>0.8 (8)
0.5 (5)</td><td rowspan="3">3:1</td><td rowspan="3">0.3</td></tr>
<tr><td>Expressway ②</td><td>High
Medium
Low</td><td>1.0 (10)
0.8 (8)
0.6 (6)</td><td>1.4 (14)
1.2 (12)
0.9 (9)</td><td>1.3 (13)
1.0 (10)
0.8 (8)</td></tr>
<tr><td>Major</td><td>High
Medium
Low</td><td>1.2 (12)
0.9 (9)
0.6 (6)</td><td>1.7 (17)
1.3 (13)
0.9 (9)</td><td>1.5 (15)
1.1 (11)
0.8 (8)</td></tr>
<tr><td>Collector</td><td>High
Medium
Low</td><td>0.8 (8)
0.6 (6)
0.4 (4)</td><td>1.2 (12)
0.9 (9)
0.6 (6)</td><td>1.0 (10)
0.8 (8)
0.5 (5)</td><td>4:1</td><td rowspan="3">0.4</td></tr>
<tr><td>Local</td><td>High
Medium
Low</td><td>0.6 (6)
0.5 (5)
0.3 (3)</td><td>0.9 (9)
0.7 (7)
0.4 (4)</td><td>0.8 (8)
0.6 (6)
0.4 (4)</td><td rowspan="2">6:1</td></tr>
<tr><td>Alleys</td><td>High
Medium
Low</td><td>0.4 (4)
0.3 (3)
0.2 (2)</td><td>0.6 (6)
0.4 (4)
0.3 (3)</td><td>0.5 (5)
0.4 (4)
0.3 (3)</td></tr>
<tr><td>Walkways/ Bikeways and Intersections</td><td colspan="6">See ANSI/IESNA RP-8 for recommended criteria and specific treatments.</td></tr>
<tr><th colspan="7">REST AREAS AND WEIGH STATIONS</th></tr>
<tr><td>Ramp Gores & Interior Roadways</td><td>All</td><td>0.4 (4)</td><td>0.6 (6)</td><td>—</td><td rowspan="2">3:1 to 4:1</td><td rowspan="3">0.4</td></tr>
<tr><td>Parking & Major Activity Areas</td><td>All</td><td>0.8 (8)</td><td>1.1 (11)</td><td>—</td></tr>
<tr><td>Minor Activity Areas</td><td>All</td><td>0.4 (4)</td><td>0.5 (5)</td><td>—</td><td>6:1</td></tr>
</table>

Notes:

1. *Average illuminance on the traveled way or on the pavement area between curb lines of curbed facilities.*

2. *Both mainline and ramps.*

3. *This assumes a separate facility. Facilities adjacent to a vehicular roadway should use the illuminance levels and uniformity ratios for that roadway.*

4. *See Section 56-5.04 for definitions of roadway facility, area, and pavement classifications.*

IDOT ILLUMINANCE DESIGN CRITERIA

Figure 56-5B

Road and Pedestrian Conflict Area		Average Luminance	Uniformity Ratio	Uniformity Ratio	Veiling Luminance Ratio
Road	**Pedestrian Conflict Area**	L_{avg} (cd/m^2)	L_{avg}/L_{min} (Maximum Allowed)	L_{max}/L_{min} (Maximum Allowed)	L_{Vmax}/L_{avg} (Maximum Allowed)
Freeway Class A	N/A	0.6	3.5	6.0	0.3
Freeway Class B	N/A	0.4	3.5	6.0	0.3
Expressway	High	1.0	3.0	5.0	0.3
	Medium	0.8	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Major	High	1.2	3.0	5.0	0.3
	Medium	0.9	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Collector	High	0.8	3.0	5.0	0.4
	Medium	0.6	3.5	6.0	0.4
	Low	0.4	4.0	8.0	0.4
Local	High	0.6	6.0	10.0	0.4
	Medium	0.5	6.0	10.0	0.4
	Low	0.3	6.0	10.0	0.4

IDOT LUMINANCE DESIGN CRITERIA

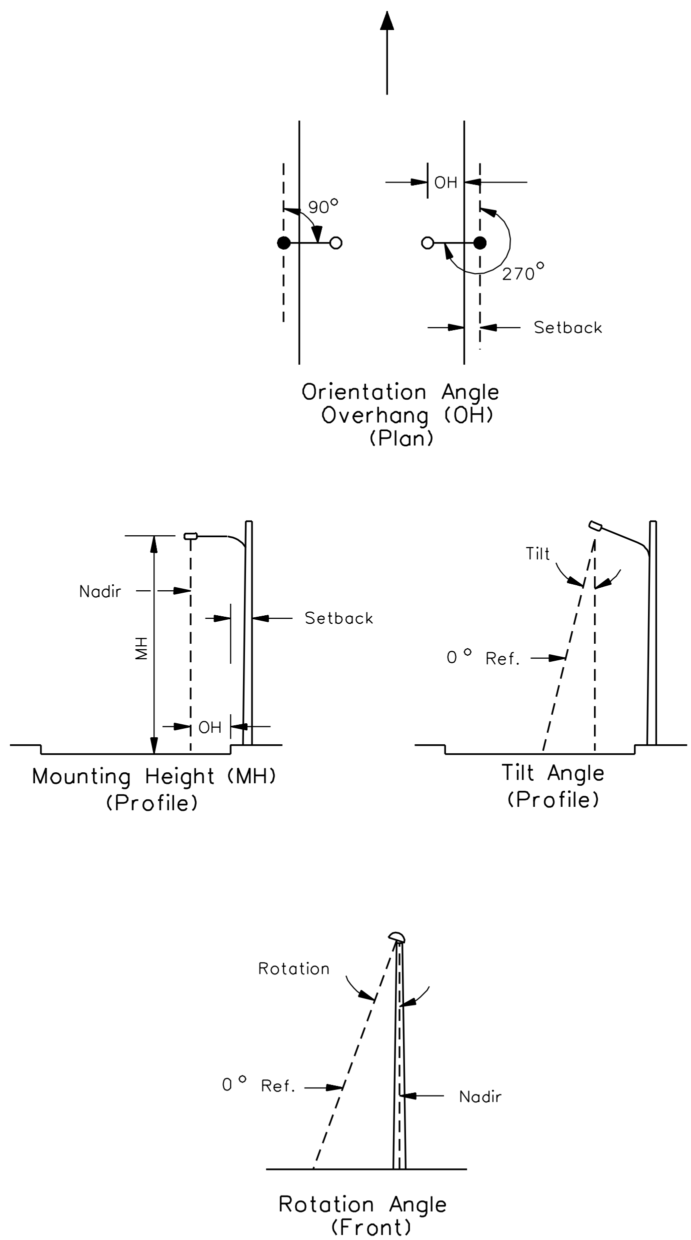
Figure 56-5C

56-5.04(e) Luminaire Considerations

Figure 56-5D illustrates the common terms used in defining and designing luminaires (e.g., mounting height, overhang). The following sections discuss design issues related to luminaires.

56-5.04(e.1) Light Distribution

Light distribution is a major factor in highway lighting design. It affects the selection of luminaire mounting height, placement, and arrangement. Specific photometric data and light distribution sheets are available from each luminaire manufacturer. Manufacturers typically classify their luminaire products based on the IES luminaire classification system. The following briefly describes the IES classification system:



LUMINAIRE GEOMETRY
Figure 56-5D

1. Vertical Light Distribution. There are three IES classifications of vertical light distribution — short, medium, and long. The selection of a particular vertical light distribution is dependent upon the luminaire mounting height and application. The following defines each type:

    a. Short Distribution (S). The maximum candlepower strikes the roadway surface between 1 and 2.25 mounting heights from the luminaire. The theoretical maximum luminaire spacing, using the short distribution, is 4.5 mounting heights.

    b. Medium Distribution (M). The maximum candlepower is between 2.25 and 3.75 mounting heights from the luminaire. The theoretical maximum luminaire spacing is 7.5 mounting heights. Medium distribution is commonly used in highway applications.

    c. Long Distribution (L). The maximum candlepower is between 3.75 and 6.0 mounting heights from the luminaire. The theoretical maximum luminaire spacing is 12 mounting heights.

    From a practical standpoint, the medium distribution is predominantly used in highway practice, and the spacing of luminaires normally does not exceed five to six mounting heights. Short distributions are not used extensively for reasons of economy, because extremely short spacing is required. At the other extreme, the long distribution is not used to any great extent because the high beam angle of maximum candlepower often produces excessive glare.

2. Lateral Light Distribution. IES has developed seven classifications for lateral light distribution. The following provides application guidelines for each luminaire type:

    a. Type I. The Type I luminaire is placed in the center of the roadway or area where lighting is required. It produces a long, narrow, oval-shaped lighted area. Some types of high-mast lighting are considered a modified form of Type I.

    b. Type I - 4-Way. This luminaire type is located over the center of the intersection and distributes the lighting along the four legs of the intersection.

    c. Type II. The Type II luminaire is placed on the side of the roadway or edge of the area to be lighted. It produces a long, narrow, oval-shaped lighted area which is usually applicable to narrower roadways.

    d. Type II - 4-Way. This luminaire type is placed at one corner of the intersection and distributes the light along the four legs of the intersection.

    e. Type III. The Type III luminaire is placed on the side of the roadway or edge of the area to be lighted. It produces an oval-shaped lighted area and is usually applicable to medium width roadways.

f. Type IV. The Type IV luminaire is placed on the side of the roadway or the edge of area to be lighted. It produces a wider, oval-shaped lighted area and is usually applicable to wide roadways.

g. Type V. The Type V luminaire is located over the center of the roadway, intersection, or area to be lighted. It produces a circular, lighted area. Type V often is used in high-mast lighting applications.

3. Control of Distribution. As the vertical light angle increases, disability and discomfort glare also increase. To distinguish the glare effects on the driver created by the light source, IES has defined the vertical control of light distribution as follows:

a. Cutoff (C). A luminaire light distribution is designated as cutoff (C) when the candlepower per 1000 lamp lumens does not numerically exceed 25 (2.5%) at an angle of 90° above nadir (i.e., horizontally), and 100 (10%) at a vertical angle 80° above nadir. This applies to any lateral angle around the luminaire.

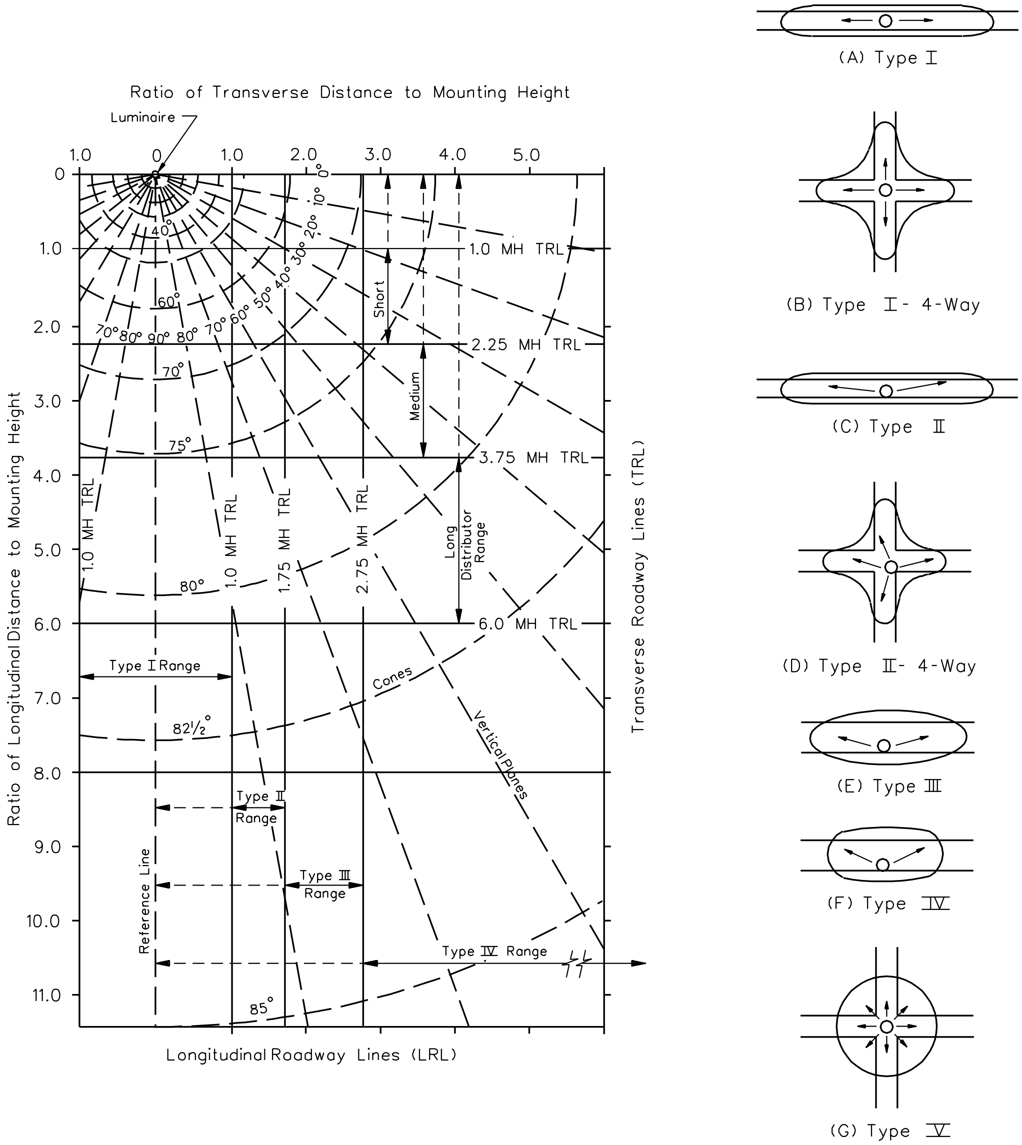
b. Semi-Cutoff (S). A luminaire light distribution is designated as semi-cutoff (S) when the candlepower per 1000 lamp lumens does not numerically exceed 50 (5%) at an angle of 90° above nadir (i.e., horizontally), and 200 (20%) at a vertical angle of 80° above nadir. This applies to any lateral angle around the luminaire.

c. Non-Cutoff (N). This classification is where there is no limitation on the zone above the maximum candlepower.

A plan view of the theoretical light distribution (i.e., roadway coverage) and schematics of the intended application of each type of IES luminaire are illustrated in Figure 56-5E.

56-5.04(e.2) Mounting Heights

Higher mounting heights used in conjunction with higher wattage luminaires enhances lighting uniformity and typically reduces the number of light poles needed to produce the same illumination level. In general, higher mounting heights tend to produce a more cost-effective design. For practical and aesthetic reasons, the mounting height should remain constant throughout the system. The manufacturer's photometric data is required to determine an appropriate mounting height. Typical mounting heights used by the Department for conventional highway lighting purposes range from 35 ft to 55 ft (10.7 m to 16.8 m). Mounting heights for light towers typically are greater than 80 ft (24 m).



PLAN VIEW OF ROADWAY COVERAGE FROM IES LUMINAIRES
Figure 56-5E

56-5.04(e.3) Coefficient of Utilization

A utilization curve is used to obtain a luminaire's coefficient of utilization (CU). Manufacturers typically provide utilization curves and isolux diagrams with each of their respective luminaire products. Figure 56-5F illustrates a sample utilization curve. The utilization curve relates to the luminaire rather than to the light source. It provides the percentage of bare lamp lumens which are utilized to light the pavement surface. If the luminaire is placed over the traveled way (i.e., out from the curb or edge of pavement), the total lumen utilization is determined by adding the street-side and curb-side (i.e., house-side) light. In essence, the utilization curve defines how much of the total lumen output reaches the area being lighted.

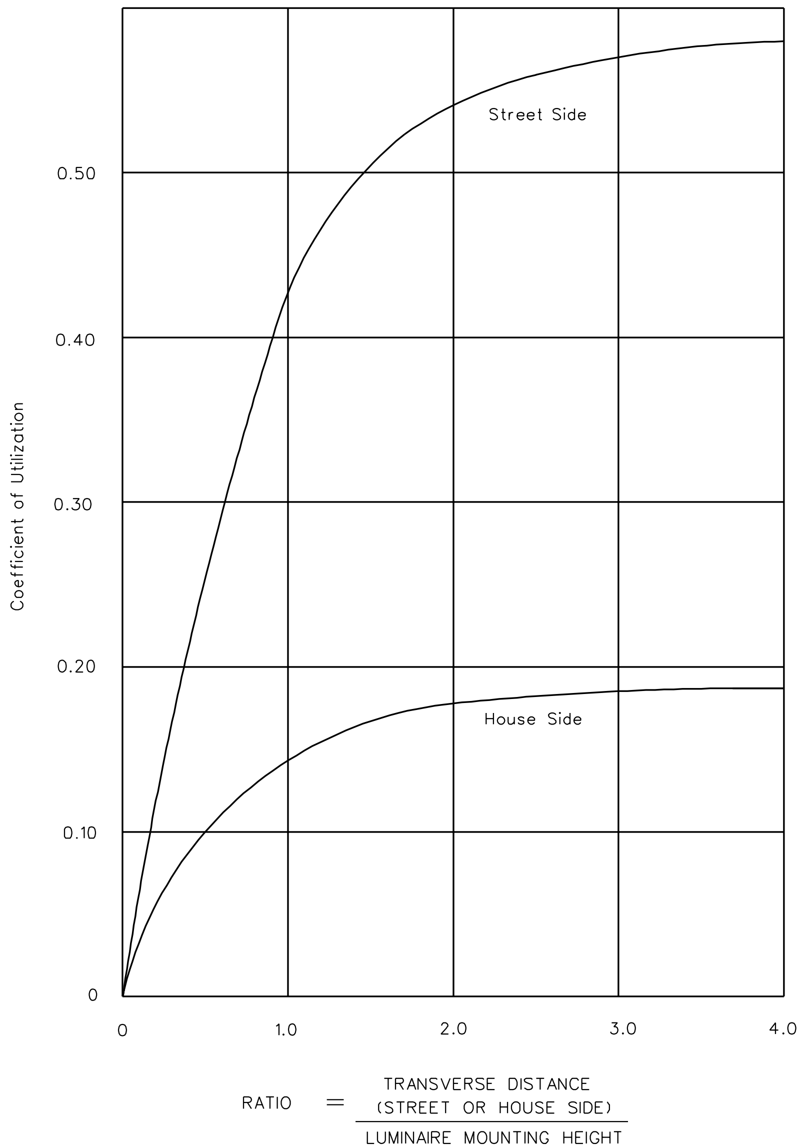
56-5.04(e.4) Light Loss Factors

The efficiency of a luminaire depreciates over time. The designer must estimate this depreciation to properly estimate the light available at the end of the lamp's serviceable life. The following briefly discusses these factors:

1. Lamp Lumen Depreciation Factor (LLD). As the lamp progresses through its serviceable life, the lumen output of the lamp decreases. This is an inherent characteristic of all lamps. The initial lamp lumen value is adjusted by a lumen depreciation factor to compensate for the anticipated lumen reduction. This assures that a minimum level of illumination will be available at the end of the assumed lamp life, even though lamp lumen depreciation has occurred. This information is usually provided by the manufacturer.

2. Luminaire Dirt Depreciation Factor (LDD). Dirt on the exterior and interior of the luminaire, and to some extent on the lamp itself, reduces the amount of light reaching the pavement. Various degrees of dirt accumulation may occur depending upon the area in which the luminaire is located. Industrial areas, automobile exhaust, diesel trucks, dust and other environs all affect the dirt accumulation on the luminaire. Higher mounting heights, however, tend to reduce the vehicle-related dirt accumulation. The relationship between the ambient environment and the expected level of dirt accumulation is shown in Figure 56-5G.

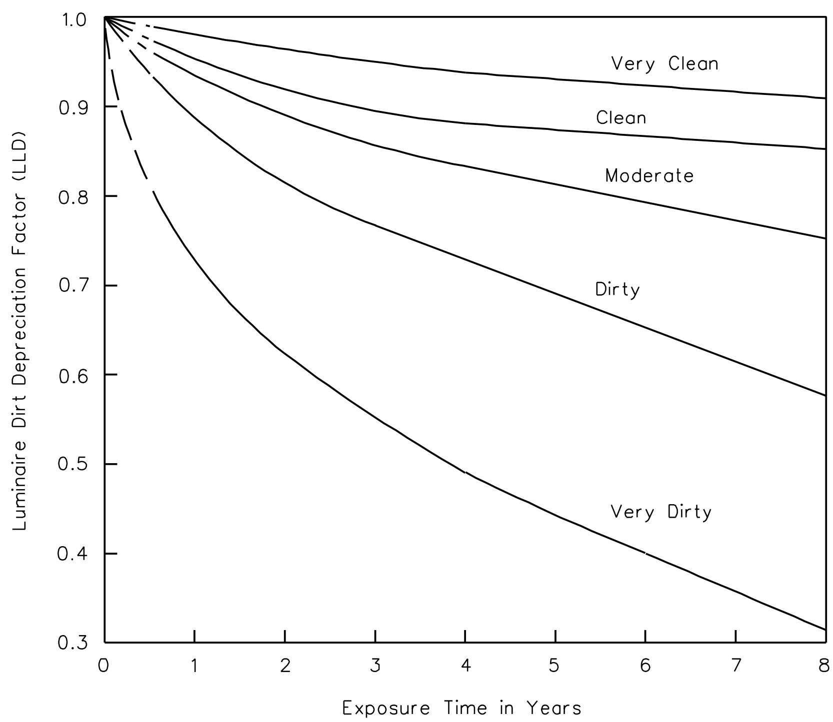
3. Maintenance Factor (MF). The maintenance factor is the combination of light loss factors used to denote the reduction of the illumination for a given area after a period of time compared to the initial illumination on the same area. It is the product of the lamp lumen depreciation factor and the luminaire dirt depreciation factor (i.e., $MF = LLD \bullet LDD$). Consult the manufacturer's data and the Electrical and Mechanical Unit for the appropriate factors to use.



Note: The utilization curve will vary with each manufacturer and luminaire type.

SAMPLE UTILIZATION CURVE

Figure 56-5F



Notes:

1. *VERY CLEAN - No nearby smoke or dust-generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is not more than 150 micrograms per cubic meter.*

2. *CLEAN - No nearby smoke or dust-generating activities. Moderate to heavy traffic. The ambient particulate level is not more than 300 micrograms per cubic meter.*

3. *MODERATE - Moderate smoke or dust-generating activities nearby. The ambient particulate level is not more than 600 micrograms per cubic meter.*

3. *DIRTY - Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.*

4. *VERY DIRTY - As above, but the luminaires are commonly enveloped by smoke or dust plumes.*

ROADWAY LUMINAIRE DIRT DEPRECIATION CURVE

Figure 56-5G

56-5.04(e.5) Luminaire Arrangement

Figure 56-5H illustrates typical luminaire arrangements for conventional highway lighting designs. Figure 56-5H also illustrates the recommended illuminance calculation points for the various arrangements.

56-5.04(f) Voltage Drop Determination

The typical highway lighting distribution circuit is 120/240 V or 240/480 V, single phase, 60-cycle alternating current. The power supply to the lighting system consists of two conductors and an insulated ground wire. The lights are connected on both sides of the circuit to obtain 240 V or 480 V at the luminaires. Use Figure 56-5I to determine the voltage drop between two adjacent luminaires.

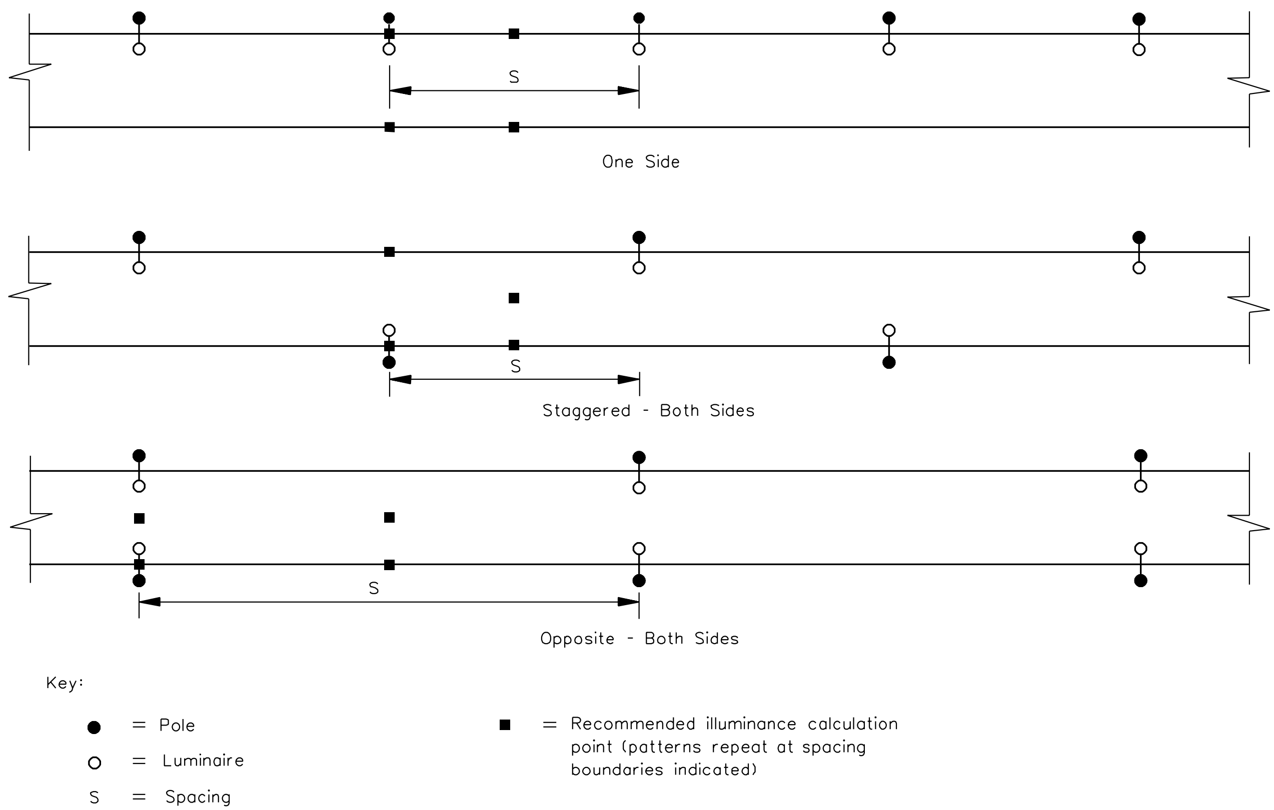
56-5.05 <u>Other Design Considerations</u>

56-5.05(a) Roadside Safety Considerations

Light poles should be installed so that they will not present a roadside hazard to the motoring public. However, the physical roadside conditions often dictate their placement. It is important to recognize this limitation. Overpasses, sign structures, guardrail, roadway curvature, right-of-way, gore clearances, proximity to roadside obstacles, and lighting equipment limitations are all physical factors that can limit the placement of light poles. The designer also must consider factors such as roadway and area classification, design speed, posted speed, safety, aesthetics, economics, and environmental impacts. In addition, there should be adequate right-of-way, driveway control, and utility clearance. Consider the following when determining the location of light poles:

1. <u>Clear Zone</u>. Where practical, place light poles outside the roadside clear zone. See Chapter 38 for additional information on roadside clear zone.

2. <u>Breakaway Supports</u>. Unless located behind a roadside barrier or crash cushion which is necessary for other safety-related reasons, conventional light poles placed within the roadside clear zone will be mounted on breakaway supports. Poles outside the clear zone also should be mounted on breakaway supports where there is a possibility of them being struck by errant vehicles. Be aware that falling poles and mast arms may endanger bystanders (e.g., pedestrians, bicyclist, motorists). Consider the following during design:



TYPICAL LUMINAIRE ARRANGEMENTS FOR CONVENTIONAL HIGHWAY LIGHTING DESIGN

Figure 56-5H

AMPS① (HPS Mag Reg Ballast)		
WATTS	**240 VOLTS**	**480 VOLTS**
250 WATTS	1.4	0.7
400 WATTS	2.1	1.1

Wire Size AWG	Circuit Resistance ohms/100 ft (ohms/100 m)	Wire Size AWG	Circuit Resistance ohms/100 ft (ohms/100 m)
14	0.0032614 (1.0700)	2	0.0002009 (0.0659)
12	0.0020498 (0.6725)	1	0.0001600 (0.0525)
10	0.0012899 (0.4232)	1/0	0.0001271 (0.0417)
8	0.0008089 (0.2654)	2/0	0.0001009 (0.0331)
6	0.0005099 (0.1673)	3/0	0.0000796 (0.0261)
4	0.0003210 (0.1053)	4/0	0.0000625 (0.0205)

Notes:

1. *Consult manufacturer's data for specific ballasts being considered.*

2. *Voltage drop is determined using the following equation:*

   $V_d = 2 \bullet D \bullet I \bullet R$ (For single-phase circuits with minimal impedance.)

   Where:

   V_d = *voltage drop in circuit (volts)*
   D = *distance in hundreds of feet (meters). See Note 3.*
   I = *current (amperes)*
   R = *resistance in ohms/100 ft (ohms/100 m). See Note 4.*

3. *Distance is the circuit length from controller to pole or from pole to pole for the segment of circuit being analyzed, measured in hundreds of feet (meters).*

4. *Resistances listed in table above are based upon stranded copper conductor at 167°F (75°C) operating temperature with an insulated covering and located in conduit. Reference source: Table 8 "Conductor Properties," Chapter 9 of the* National Electrical Code*.*

VOLTAGE DROP BETWEEN LUMINAIRES
Figure 56-5I

a. Pedestrians. In areas where pedestrians, bicyclists, or building structures and windows may be struck by falling poles or mast arms after a crash, evaluate the relative risks of mounting the light pole on a breakaway support. Examples of locations where the hazard potential of providing a breakaway support to pedestrian traffic would be greater than a non-breakaway support would be to vehicular traffic include transportation terminals, sports stadiums and associated parking areas, tourist attractions, school zones, central business districts, and local residential neighborhoods where the posted speed limit is 30 mph (50 km/h) or less. In these locations, non-breakaway supports will be used. Other locations which require the use of non-breakaway supports, regardless of the amount of pedestrian traffic, are rest area and weigh station parking lots and combination luminaire and traffic signal poles.

b. Breakaway Bases. All breakaway devices will comply with the applicable AASHTO requirements for breakaway structural supports.

c. Breakaway Support Stub. Any substantial portion of the breakaway support that will remain after the light pole has been struck will have a maximum projection of 4 in (100 mm) above the finished grade within a 5 ft (1.5 m) chord above the foundation in accordance with AASHTO criteria. See Chapter 38.

d. Wiring. All light poles that require breakaway supports will be served by underground wiring and designed with quick disconnect splices.

e. Light Towers. Light Towers used in high-mast lighting applications will not be mounted on breakaway supports. Also, they will not be located within the roadside clear zone unless shielded by guardrail or crash cushions.

f. Bridge Parapets and Concrete Barriers. Where poles are mounted atop bridge parapets and concrete barriers, they will be mounted on non-breakaway supports.

3. Gore Areas. Where practical, locate light poles outside the gore areas of exit and entrance ramps. No lighting support will be placed in a gore area.

4. Horizontal Curves. Place light poles on the inside of sharp curves and loops. Where poles are located on the inside radius of superelevated roadways, provide sufficient clearance to avoid being struck by trucks.

5. Maintenance. When determining pole locations, consider the hazards which will be encountered while performing maintenance on the lighting equipment.

6. Barriers. Use the criteria provided in Chapter 38 to design and place light poles in conjunction with roadside barriers. Consider the following additional guidelines:

a. Placement. Where a roadside barrier is provided, place all light poles behind the barrier.

b. Deflection. Light poles placed behind a roadside barrier should be offset by at least the deflection distance of the barrier (see Chapter 38). This will allow the railing to deflect without hitting the pole. If this clearance distance is not available, such as in extreme side slope conditions, designate the stiffening of the rail.

c. Concrete Barriers. Light poles that are shielded by a rigid or non-yielding barrier do not require a breakaway support.

d. Impact Attenuators. Locate light poles, either with or without a breakaway support, such that they will not interfere with the functional operation of any impact attenuator or other safety device.

7. Protection Features. Do not use protection features, such as barriers, for the primary purpose of protecting a light pole.

8. Longitudinal Adjustments. Locate light poles to balance both safety and lighting needs. Adjustments on the order of 2% of the longitudinal spacing is permissible in the field to accommodate utilities or drainage facilities provided the new location does not constitute a roadside hazard. Larger adjustments need approval by the Central Office.

56-5.05(b) Foundation, Pole Mounting, and Structural Considerations

The *Standard Specifications, Highway Standards,* and the electrical detail sheets provide pole mounting details and details for foundation materials, depth, width, reinforcing, etc. When designing lighting systems, also consider the following:

1. Foundation Height Relative to Final Grade. For other than light towers, design pole foundations flush with the high edge of the surrounding grade. This permits drainage necessary to protect the foundation and reduces the likelihood of the foundation intensifying a collision. The foundation also is less likely to be destroyed during a collision. When located within the clear zone, ensure that the foundation and fractured breakaway device does not protrude more than 4 in (100 mm) above the finished grade within a 5 ft (1.5 m) chord. See Chapter 38 for additional information on clear zones.

2. Steel Foundations. The steel (i.e., helix screw-in type) foundation is one that is commonly used by the Department for conventional light poles. This foundation is placed in undisturbed earth using a clockwise rotation similar to a common screw. The diameter of the steel tube ranges from 8 in to 10 in (200 mm to 250 mm) and is typically 6 ft (1.8 m) long. Shorter lengths may be appropriate for foundations in areas with shallow bedrock. The steel foundation will accommodate poles with 11.5 in and 15 in

(292 mm and 381 mm) bolt circles for luminaire mounting heights ranging from 40 ft to 50 ft (12 m to 16 m).

3. Light Tower Foundations. Foundations for light towers used in high-mast lighting applications typically require specialized designs and soil surveys to ensure adequate support. A 4 ft (1.2 m) diameter reinforced concrete foundation, to a depth as required by the soils analysis, usually is adequate for towers accommodating 80 ft (24.4 m) luminaire mounting heights. The top 18 in (450 mm) of the foundation is formed below grade. Below this depth, ensure that the foundation is designed to be poured monolithically against the undisturbed earth of the bored hole. Specify the foundation depth on the lighting plans. Additionally, include a concrete work pad at the base of the tower.

4. Foundations for Temporary Lighting. Foundations for temporary lighting will be determined on a case-by-case basis. This may include direct embedment of wood poles to a depth of from 5.5 ft (1.7 m), for 30 ft (9 m) poles, to 12 ft (3.6 m), for 65 ft (19.8 m) poles. The use of butt base anchors also may be considered.

5. Pole Mounting on Parapets. Poles for bridge lighting typically are mounted on specially designed concrete parapet sections. Ensure that the mounting design includes the necessary non-breakaway, high-strength bolts, leveling plate, and vibration pad.

6. Structural Design. Poles will be designed and fabricated to meet or exceed AASHTO requirements as documented in *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* and NCHRP Report 411. See the IDOT *Standard Specifications* for the appropriate design criteria (e.g., wind loading, gust factor, luminaire mass and effective area).

56-5.05(c) Other Considerations

In addition to the items discussed in the previous sections, consider the following when designing the highway lighting system:

1. Signs. Place light poles to minimize interference with the driver's view of the roadway and any highway signs. Do not permit luminaire brightness to seriously detract from the legibility of signs at night.

2. Structures. Place light poles sufficiently away from overhead bridges and sign structures to minimize glare and distracting shadows on the roadway surface.

3. Trees. Insufficiently pruned trees can cause shadows on the roadway surface and reduce the luminaire's effectiveness. Design the luminaire with a height and mast-arm length to negate such adverse effects.

56-6 HIGH-MAST LIGHTING DESIGN

In general, the design of high-mast lighting systems follows the same design procedures as discussed in Section 56-5. In addition, consider the following:

1. Light Source. Generally, either 400 W, 750 W, or 1000 W HPS lamps should be used. The number of luminaires required will be determined by the area to be lighted. As a general starting point, it can be assumed that mounting heights of approximately 100 feet (30 m) will require 400,000 lm, 600,000 lm for mounting heights of approximately 115 feet to 130 feet (35 m to 40 m), and 800,000 lm for mounting heights of approximately 150 feet (45 m). The number of luminaires per pole typically ranges from 4 to 6 luminaires.

2. Mounting Heights. Mounting heights in high-mast lighting applications range from 80 feet to 200 feet (24 m to 60 m). In general, heights of 100 feet to 150 feet (30 m to 50 m) have exhibited the most practical designs. Greater mounting heights require more luminaires to maintain illumination levels. However, greater heights allow for fewer poles and provide better light uniformity.

3. Location. In determining the location of light towers, review the plan view of the area to determine the more critical areas requiring lighting. In selecting tower locations, consider the following:

    a. Critical Areas. Locate light towers so that the highest localized levels of illumination fall within the critical traffic areas (e.g., freeway/ramp junctions, ramp terminals, merge points).

    b. Roadside Safety. Locate light towers outside the roadside clear zone and a sufficient distance from the roadway so that the probability of a collision is virtually eliminated. Do not place light towers on the end of long tangents.

    c. Signs. Locate light towers so that they are not within the driver's direct line of sight to highway signs.

4. Design. There are generally two methodologies for checking the adequacy of light uniformity — the point-by-point method and the template method. The point-by-point method checks illumination by using the manufacturer's isolux diagram. The total illumination at a point is determined by the sum of the contributions of illumination from all mast assemblies within the effective range of the point. Due to the numerous calculations, use Department-approved computer software to make these determinations. The template methodology uses isolux templates to determine the appropriate locations for light towers. The templates may be moved around to ensure that the minimum maintained illumination is provided and the uniformity ratio has been satisfied. Give consideration to adjacent land use during the analysis.

5. Navigable Airspace. Where lighting projects are being considered in close proximity to an active airfield or airport, consider the impact the height of the light tower has on navigable airspace. For additional information, consult the FAA Advisory Circular AC 70/7460-2J *Proposed Construction or Alteration of Objects that May Affect the Navigable Airspace.*